U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER KUBOMURA 1
TRANMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U S APPLICATION NO (If known,see 37 CFR 1 5) **09/720372**

INTERNATIONAL APPLICATION NO. PCT/JP00/02652	INTERNATIONAL FILING DATE 24 April 2000	PRIORITY CLAIMED 23 April 1999

TITLE OF INVENTION
FIBER-REINFORCED RESIN COMPOSITE MATERIAL HAVING REDUCED COEFFICIENT OF LINEAR EXPANSION

APPLICANT(S) FOR DO/EO/US
Kenji KUBOMURA et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] The US has been elected in a Demand by the expiration of 19 months from the priority date (PCT Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. [ ] is attached hereto (required only if not transmitted by the International Bureau).
   - b. [X] has been communicated by the International Bureau.
   - c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   - a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. [ ] have been communicated by the International Bureau.
   - c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   - d. [X] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4))
10. [ ] An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An Assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [X] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information:
    - [X] Courtesy copy of the International Application as filed.
    - [X] Courtesy copy of the first page of the International Publication (WO 00/ 64668).
    - [X] Formal drawings, 3 sheets, Figures 1-4.
    - [X] Courtesy Copy of the International Search Report.
    - [ ] Applicant claims small entity status. See 37 CFR 1.27.

U.S. APPLICATION NO (if known, see 37 CFR 1 5)	International Application No	Attorney's Docket No
09/720372	PCT/JP00/02652	KUBOMURA 1

17. [xx] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a)(1) –(5):

Neither international preliminary examination fee (37 CFR 1.482)
nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO
and International Search Report not prepared by the EPO or JPO.................$1000.00

International preliminary examination fee (37 CFR 1.482) not paid to
USPTO but International Search Report prepared by the EPO or JPO............$860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but
international search fee (37 CFR 1.445(a)(2)) paid to USPTO....................$710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)
but all claims did not satisfy provisions of PCT Article 33(1)-(4)...............$690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)
and all claims satisfied provisions of PCT Article 33(1)-(4).........................$100.00

CALCULATIONS PTO USE ONLY

ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860.00	
Surcharge of $130.00 for furnishing the oath or declaration later than [X] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 130.00	

Claims as Originally Presented	Number Filed	Number Extra	Rate		
Total Claims	6 - 20		X $18.00	$	
Independent Claims	2 - 3		X $80.00	$	
Multiple Dependent Claims (if applicable)			+$270.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 990.00	

Claims After Post Filing Prel. Amend	Number Filed	Number Extra	Rate		
Total Claims	20 - 20		X $18.00	$	
Independent Claims	2 - 3		X $78.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 990.00	

Reduction of ½ for filing by small entity, if applicable. Applicant claims small entity status. See 37 CFR 1.27.	$	
SUBTOTAL =	$	
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).	$	
TOTAL NATIONAL FEE =	$ 990.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$ 990.00	
	Amount to be: refunded	$
	charged	$

a. [ ] A check in the amount of $_____ to cover the above fees is enclosed

b. [X] Credit Card Payment Form (PTO-2038), authorizing payment in the amount of $ 990.00, is attached.

c. [ ] Please charge my Deposit Account No. 02-4035 in the amount of $_____ to cover the above fees.
A duplicate copy of this sheet is enclosed.

d. [XX] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-4035. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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TEL: (202) 628-5197
FAX: (202) 737-3528
Date of this submission: **December 26, 2000**

SIGNATURE
Sheridan Neimark
NAME
20,520
REGISTRATION NUMBER

Form PTO-1390 (as slightly revised by Browdy and Neimark)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	Art Unit:
Kenji KUBOMURA et al.	)	
	)	
	)	
	)	
IA No.: PCT/JP00/02652	)	
	)	Washington, D.C.
IA Filed: 24 April 2000	)	
	)	
U.S. App. No.:	)	
(Not Yet Assigned)	)	
	)	December 26, 2000
National Filing Date:	)	
(Not Yet Received)	)	
	)	
For: FIBER-REINFORCED RESIN …	)	Docket No.:KUBOMURA 1

PRELIMINARY AMENDMENT

Honorable Commissioner for Patents and Trademarks
Washington, D.C. 20231

Sir:

Contemporaneous with the filing of this case and prior to calculation of the filing fee, kindly amend as follows:

IN THE SPECIFICATION

After the title please insert the following paragraph:

--The present application is the national stage under 35 U.S.C. 371 of PCT/JP00/02652, filed 24 April 2000.--

IN THE CLAIMS

Claim 3, line 3, delete "claims 1 or 2", and insert therefor --claim 1--.

Claim 5, line 3, delete "at least one of claims 1 through 4", and insert therefor --claim 1--.

Claim 6, line 4, delete "one of claims 1 through 5", and insert therefor --claim 1--.

If, inadvertently, a proper multiple dependent claim has not been amended to reduce it to single dependency, please amend it to be dependent solely on the first-mentioned claim, or, if that is not possible, please cancel the claim and notify the undersigned.
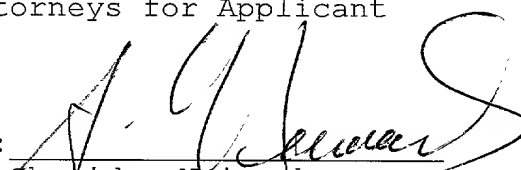
REMARKS

The above amendment to the specification is being made to insert reference to the PCT application of which the present case is a U.S. national stage. The above amendments to the claims are being made in order to eliminate multiple dependency and for the purpose of reducing the filing fee. Please enter this amendment prior to calculation of the filing fee in this case.

Favorable consideration and allowance are earnestly solicited.

Respectfully submitted,
BROWDY AND NEIMARK, P.L.L.C.
Attorneys for Applicant

By: _____
Sheridan Neimark
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	Art Unit:
Kenji KUBOMURA et al.	)	
	)	
	)	
	)	
IA No.: PCT/JP00/02652	)	
	)	Washington, D.C.
IA Filed: 24 April 2000	)	
	)	
U.S. App. No.:	)	
(Not Yet Assigned)	)	
	)	December 26, 2000
National Filing Date:	)	
(Not Yet Received)	)	
	)	
For: FIBER-REINFORCED RESIN …	)	Docket No.:KUBOMURA 1

SUPPLEMENTAL PRELIMINARY AMENDMENT

Honorable Commissioner for Patents and Trademarks
Washington, D.C. 20231

Sir:

Prior to examination upon the merits, kindly amend as

follows:

IN THE CLAIMS

Please add the following claims:

—7.   In-plane quasi-isotropic fiber reinforced resin

composite material having a reduced coefficient of linear

expansion as claimed in claim 2, wherein said coefficient of

linear expansion is reduced by combining sheets woven by one

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kind or more than reinforced fibers of which a coefficient of linear expansion is controlled by a three dimensional structure of twisting yarn, biaxial textile or triaxial textile.

8. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion selected from material claimed in claim 7.

9. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion selected from material claimed in claim 2.

10. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion selected from material claimed in claim 3.

11. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion selected from material claimed in claim 7.

12. Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 11,

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wherein a coefficient of linear expansion of said material is controlled.

13.   Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 10, wherein a coefficient of linear expansion of said material is controlled.

14.   Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 9, wherein a coefficient of linear expansion of said material is controlled.

15.   Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 8, wherein a coefficient of linear expansion of said material is controlled.

16. Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 7, wherein a coefficient of linear expansion of said material is controlled.

17. Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 5, wherein a coefficient of linear expansion of said material is controlled.

18. Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in claim 4, wherein a coefficient of linear expansion of said material is controlled.

19. Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber

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reinforced resin composite material as claimed in claim 3, $s\nu$
wherein a coefficient of linear expansion of said material is
controlled.

20. Yarn prepreg, one-way prepreg, biaxial textile,
triaxial textile, four axial textile or a prepreg formed by
these textile used for in-plane quasi-isotropic fiber
reinforced resin composite material as claimed in claim 2,
wherein a coefficient of linear expansion of said material is
controlled.

REMARKS

Claims 1-20 presently appear in this case. The
above amendments to the claims are being made in order to add
new claims and to restore at least partly the varying scope of
claims which was eliminated by the elimination of multiple
dependencies in the claims.

Favorable consideration is earnestly solicited.

Respectfully submitted,

BROWDY AND NEIMARK, P.L.L.C.
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SPECIFICATION

FIBER REINFORCED RESIN COMPOSITE MATERIAL

HAVING REDUCED COEFFICIENT OF LINEAR EXPANSION

Field of the Invention

The present invention relates to fiber reinforced resin material having a reduced coefficient of linear expansion, particular relates to fiber reinforced resin material having a coefficient of linear expansion of substantially zero.

Background of the Invention

In a conventional art, fiber reinforced resin composite material having a reduced coefficient of linear expansion can accomplish physical and chemical characteristics suitable for its purpose by selecting a combination of reinforced fiber and resin matrix, and has been broadly used. Particularly, fiber reinforced resin composite material is strong with respect to chemical reaction and corrosion environment, and has a low specific gravity and high stiffness in general. The material has been broadly utilized as structures and parts in the field of an aircraft and space environment, applicable to parts of fine machinery devices, material of construction or sporting goods.

In the case of utilizing material as structural parts for fine tools used in an environment thermally influenced, it would become a serious problem caused by thermal expansion in accordance with a temperature varying. For example, in the case of an artificial satellite, a temperature at a side confronting with sun and a temperature at a side opposite to sun are remarkably different so that installed fine tools are baneful influenced

by thermal expansion in such an environment. In a field of a semiconductor manufacturing device, an optical tool and a fine processing device, baneful influence caused by thermal expansion should be reduced as less as possible.

In a conventional art, although material having reduced coefficient of thermal expansion such as Inver alloy, quartz glass, carbon fiber reinforced resin composite material has been used, these are metal, silica system material or limited material. In the case of the material, its utility, strength, specific gravity and manufacturing cost would be restricted. It is required a coefficient of liner expansion as less as possible so as to utilize a fiber reinforced resin composite material in the various field described above. In order to control a coefficient of linear expansion of fiber reinforced resin composite material, it is prefer to use reinforced fiber and matrix resin of which a coefficient of linear expansion is low or substantially zero. However, it is not an actual way to provide the characteristic described above with respect to the both of the reinforced fiber and the resin matrix. There has been an experiment to reduce a total coefficient of linearly expansion by combining fiber having a negative coefficient of linear expansion along a fiber direction and fiber having a positive coefficient of linear expansion along the fiber direction so as to cancel these coefficients each other.

However, in the method, it would be difficult for the both of reinforced fiber and resin matrix to provide suitable characteristics. Upon considering strength and heat-resistant of the fiber reinforced resin composite material originally required, a material selection is so restricted.

A factor for determining a coefficient of linear expansion

of a plate member and a furnished product made of reinforced fiber
resin composite material is not only a coefficient of linear
expansion of these materials but also a blending ratio of the
reinforced fiber and the matrix resin. Depending on a kind of
reinforced fiber, such as monofilament, yarn doubling and yarn
twisting, a structure of prepreg and a laminating condition such
as a three dimensional laminating structure formed by
biaxial/triaxial textile with one-way prepreg aligned along one
direction and a structure of filaments and their laminated
structure.

The present inventors reviewed a combination of reinforced
fibers and their kinds, a selected structure of the reinforced
fiber and a prepreg so as to provide reinforced fiber resin
composite material having superior characteristics wherein the
inventors found factors how a coefficient of linear expansion
can be effectively and finely reduced.

Disclosure of the Invention

Regarding an in-plane quasi-isotropic material formed by
reinforced fiber resin composite material according to the present
invention, two kinds or more than reinforced fibers are combined,
wherein at least one reinforced fiber having a negative
coefficient of linear expansion is included. A respective sheet
woven by one kind or more than reinforced fibers of which each
coefficient of linear expansion is controlled is combined so as
to reduce a total coefficient of linear expansion, wherein two
kinds or more than reinforced fibers are formed as a strand in
a condition of monofilament, yarn doubling or twisting yarn.

Under the above structure, a plurality of sheets formed
by one kind or more than reinforced fiber in which a three

dimensional structure of twisting yarn, biaxial textile or triaxial textile controls its coefficient of linear expansion are combined so as to provide an in-plane quasi-isotropic material by providing reinforced fiber resin composite material wherein the coefficient of linear expansion is reduced.

Further, two or more than sheets made of reinforced fiber are combined wherein a coefficient of linear expansion of the respective reinforced fiber is different each other and at least one reinforced fiber has a negative coefficient of linear expansion so as to provide an in-plane quasi-isotropic material by providing reinforced fiber resin composite material wherein the coefficient of linear expansion is reduced. These kinds of reinforced fibers can be selected from various selections. Even if a reinforced fiber had an excellent elastic modulus and excellent chemical characteristics, the reinforced fiber could not have been utilized since the reinforced fiber has a negative coefficient of linear expansion. Unless a reinforced fiber had a proper coefficient of linear expansion, the reinforced fiber could not have been utilized. Nowadays, these reinforced fibers can be utilized in the present invention.

By combining these reinforced fibers in a form of one prepreg or a plurality of prepreg, a total coefficient of linear expansion is controlled to a predetermined level. After forming reinforced fiber resin composite material with these reinforced fibers, a final coefficient of the material would be within a preferable range, for example, substantially zero. Regarding the combined reinforced fibers, the respective coefficient of linear expansion of monofilament is not so important. The coefficient of linear expansion of the reinforced fiber with respect to a resin matrix and the coefficient of the resin matrix are finally controlled

so that a reduced coefficient of linear expansion can be provided.
Upon considering a structure of reinforced fiber formed by
monofilament, a coefficient of linear expansion of the combined
reinforced fibers is controlled by selecting kinds and number
of reinforced fibers and its blending ratio.

Embodiments of these reinforced fibers may be yarn doubling
of which the total coefficient of linear expansion is controlled
or a strand formed by two kinds or more than reinforced fibers
are bundled.

In the present invention as claimed in claim 3, a coefficient
of linear expansion is controlled by utilizing a fact that the
coefficient is varied by a three dimensional structure of
reinforced fiber. A three dimensional structure is formed by
twisting yarn in which reinforced fibers are twisted so that a
substantial length becomes longer and a twisting condition is
changed caused by expansion/contraction of the twisting yarn.
As the result, an apparent coefficient of linear expansion is
changed. Thus, a substantial coefficient of linear expansion
can be varied by utilizing such a twisting yarn. By preparing
a prepreg formed by reinforced fibers made of the twisting yarn,
a coefficient of linear expansion of a fiber reinforced structure
can be controlled by utilizing the same kind of reinforced fiber.
As similarly, by preparing one-way prepreg, prepreg formed by
biaxial textile or prepreg formed by triaxial textile, the
substantial length of the fiber is different depending on their
three dimensional textile structures. Apparent coefficient of
linear expansion is varied caused by expansion/contraction of
the prepreg. Upon considering the difference of the coefficients
of linear expansion caused by the structures of the prepregs,
the total coefficient of linear expansion of fiber reinforced

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resin composite material can be reduced to a predetermined level.

In the present invention as claimed in claim 4, a coefficient of linear expansion of a laminated reinforced structure is controlled by combining sheets with different coefficients of linear expansion made of reinforced fibers having different coefficients of linear expansion. Regarding these sheets having different linear expansion ratio, a sheet aligned along one direction and a sheet formed by biaxial/triaxial textile may be utilized. A coefficient of linear expansion is controlled by laminating a predetermined number of pairs including two or more than sheets having different coefficients of linear expansion so as to reduce a coefficient of linear expansion of fiber reinforced resin composite material to a predetermined level as an in-plane quasi-isotropic material.

As described above, by combining reinforced fibers having different coefficient of linear expansion, or considering a three dimensional structure of sheets, the coefficient of linear expansion is controlled by laminating sheets formed by reinforced fibers having a different coefficient of linear expansion so that a coefficient of linear expansion of reinforced fiber resin composite material can be controlled to a predetermined level. In addition, by combining these structures, a total coefficient of liner expansion can be controlled more effectively and easily.

Brief Description of the Drawings

Fig. 1 is a schematic view for explaining a control of a coefficient of linear expansion of fiber reinforced resin composite material.

Fig. 2 shows a structure bundled by reinforced fibers A and B, wherein each coefficient of linear expansion is different.

Fig. 3 shows an example of a prepreg sheet formed by bundled fibers of which the respective coefficient of linear expansion is different each other. Fig. 3(a) shows a one-way prepreg sheet, Fig. 3(b) shows a biaxial prepreg sheet and Fig. 3(c) shows a triaxial prepreg sheet.

Fig. 4 shows an example of fiber bundle having a constant coefficient of linear expansion formed by reinforced fibers having different coefficient of linear expansion. Fig. 4(a) is an example of the one-way direction prepreg; Fig. 4(b) is an example of the biaxial prepreg sheet; and Fig. 4(c) is an example of the triaxial prepreg sheet.

The Preferred Embodiment of the Present Invention

With reference to the accompanying drawings, it will be explained a concrete structure of fiber reinforced resin composite material according to the present invention and its embodiments.

Fig. 1 shows a principle how a coefficient of linear expansion of an in-plane quasi-isotropic plate according to the present invention is controlled to a predetermined level by combining a sheet 1 and a sheet 2 having different coefficient of linear expansion each other. In Fig. 1, one reinforced fiber has a negative coefficient of linear expansion. Regarding the other reinforced fiber, its coefficient may be relatively large (positive). By alternatively laminating the sheet 1 and the sheet 2 as shown in Fig. 1 in order to provide an in-plate quasi-isotropic plate and thermally hardening the plate, a coefficient of linear expansion formed as fiber reinforced resin composite material can be controlled to zero or a predetermined level.

Under the structure described above, a coefficient of linear expansion of each reinforced fiber and a coefficient of linear

expansion of matrix resin can be selected easily. Under the combination, fiber having a high elastic coefficient and reinforced fiber having excellent chemical characteristics may be blended with reinforced fiber of which material is suitable for controlling a coefficient of linear expansion so as to provide new material having the most preferable characteristics.

Fig. 2 shows a bundle of reinforced fibers formed by at least two kinds of fibers, a reinforced fiber A with one coefficient of linear expansion and a reinforced fiber B with a different coefficient of linear expansion. By blending these two kinds of reinforced fibers, a strand of which a coefficient of linear expansion is controlled to a predetermined value can be obtained.

By bundling reinforced fibers, bundled fibers can be treated as one material having a constant coefficient of linear expansion so that composite material can be formed by a one-way prepreg by aligning these bundles along one direction, a biaxial textile prepreg or a triaxial textile prepreg. Accordingly, by laminating a predetermined number of prepreg formed by fiber bundles having a constant coefficient of linear expansion, a coefficient of linear expansion of an in-plate quasi-isotropic plate can be controlled.

Fig. 3(a) shows a one-way prepreg wherein fiber bundles A and B formed by reinforced fibers having different coefficient of linear expansion are aligned along one direction, Fig. 3(b) shows a biaxial textile prepreg and Fig. 3(c) shows a triaxial textile prepreg. The coefficient of linear expansion can be controlled to the predetermined level by alternatively aligning fiber bundles A and B having different coefficient of linear expansion each other. A product process of the material is as similar as that of normal reinforced fiber resin composite

material.

Fig. 4(a) through 4(c) shows examples of fiber bundles 3 having a predetermined value of linear expansion by blending reinforced fibers having different coefficient of linear expansion as shown in Fig. 2, respectively. In these examples, the fiber bundles have the same coefficient of linear expansion so that the fiber bundles can be treated as similar as normal fiber bundles. In an example as shown in Fig. 4(a), a diameter of a monofilament is 4 to 50μm and number of fibers are 10 to 1000,000. By aligning these fibers as shown in Fig.4(a), one-way prepreg having a thickness of 10 to 500μm and a width of 1 to 150cm can be provided.

Fig. 4(b) and 4(c) is examples of biaxial textile and triaxial textile, respectively.

Regarding a combination of reinforced fibers according to the present invention, actual cases of the combination of reinforced fiber and resin matrix are shown as follows:

(1) Characteristics of epoxy system resin used for a matrix

Tensile elastic modulus: 360kg/mm^2

Poisson ratio: 0.35

Thermal expansion ratio: 60ppm/℃

(2) Characteristics of Reinforced fiber: fiber type, coefficient of linear expansion and tensile elastic modulus of reinforced fiber are shown in Table 1

Table 1: fiber type, coefficient of linear expansion and tensile elastic modulus of reinforced fiber

Fiber type	Tensile elastic modulus along a fiber direction kgf/mm^2	Coefficient of linear expansion along a fiber direction x10^{-6}/℃
PAN-based carbon fiber (M50J)	48,500	-1
PAN-based carbon fiber (M50J)	60,000	-1.1
PAN-based carbon fiber (M50J)	23,500	-0.41
PAN-based carbon fiber (M50J)	35,000	-0.73
Pitch-based carbon fiber (YS-35)	35,690	-1.1
Pitch-based carbon fiber (YS-60)	61,183	-1.5
Pitch-based carbon fiber (YS-70)	71,972	-1.5
Aramid fiber (K149)	19,000	-2
PBO fiber (zairon)	28,500	-6

PBO: Polyparaphenylene Benzo Oxazale

Zairon: trademark registered by TOYO BOSEKI Co., Ltd.

A sheet is formed by arranging these reinforced fibers along one direction and immersed in matrix resin as one-way directional material. In the case of an in-plane quasi-isotropic plate formed by laminating these sheets, a coefficient of linear expansion of the plate is calculated by the following equation (the equation and its explanation were disclosed by one of inventors at a seminar of Composite Material at Hokuriku division on April 14, 1999).

These reinforced fibers are formed as one-way sheet, biaxial textile or triaxial textile. An in-plane quasi-isotropic material is formed by laminating these sheets and hardened so as to form composite material. The coefficient of linear expansion of the respective fiber and sheet in the composite material can be judged in a macro view. Even if the structure of the composite material is different, the total coefficient can be treated usually.

A blend ratio in the case of bundled fibers as shown in

Fig. 2 formed by blending two kinds of fibers having different coefficient of linear expansion is recognized as a hybrid ratio. A ratio of combining a yarn prepreg, a one-way prepreg, a biaxial prepreg, a triaxial prepreg and a four-axial prepreg formed by bundled fibers of two kinds of fibers having the different coefficient of linear expansion can be treated as a hybrid ratio.

$$\alpha = (E_L * \alpha_L + E_L * \alpha_T + \mu_{LT} * E_L * \alpha_L + \mu_{LT} * E_L * (\alpha_L + \alpha_T)) / (E_L + E_T + 2\mu_{LT} * E_L)$$

In the equation,

E_L: elastic modulus of one-way material along a fiber direction

E_T: elastic modulus of one-way material along a direction perpendicular to the fiber direction

μ_{LT}:   Poisson ratio

α_L: coefficient of linear expansion of one-way material along a fiber direction

α_T: coefficient of linear expansion of one-way material along a direction perpendicular to the fiber direction

Material characteristics of these one-way materials are determined by kind of fiber and resin and a content ratio of fiber. Regarding characteristics of reinforced fiber, an elastic modulus of one-way material along a transversal direction or a crimp ratio of textile are influenced. However, there is not sufficient data about them. Therefore, regarding the influence caused by these factors are estimated based on an experimental knowledge and checked actually.

(3) An in-plane quasi-isotropic plate is formed by laminating sheets made of one-way prepreg and prepreg formed by biaxial textile in accordance with the following method.

(a)   A prepreg is formed by a pair of one-way prepreg formed by a layer 1 and a layer 2 as shown in Fig. 1. These pairs are laminated along directions of 0° , 90° , 45° , -45° , -45° ,

45°, 90°, 0° in order so as to form an in-plane quasi-isotropic plate.

(b)   Eight sheets of one-way prepregs having the same characteristics as shown in Fig. 4(a) formed by fibers as shown in Fig. 2 are laminated along direction of 0°, 90°, 45°, -45°, -45°, 45°, 90°, 0° in order so as to form an in-plane quasi-isotropic plate.

(c)   In the case of biaxial textile, if a crimp ratio is controlled to reduce, the textile is not so different from the one-way material and substantially utilized as same as the one-way prepreg.   The similar plate can be produced by laminating sheets of the biaxial textile along a direction of 0°, 45°, 45°, 0°.   These four prepregs are same material formed by yarn doubling of two kinds or more than fibers, combing wool or a textile alternatively woven by these fiber bundles. Such a structure is shown in Fig. 2, Fig. 3(b) and Fig. 4(b).

(d)   Regarding an in-plane quasi-isotropic plate formed by the above described method, a relation between a hybrid ratio calculated by the above equation and a coefficient of thermal expansion is shown in Table 2.

Table 2: Hybrid ratio of fiber and coefficient of thermal expansion of an in-plane quasi-isotropic plate

Fiber type		Hybrid ratio (%) = weight of fiber A/(weight of fiber A + weight of fiber B) x 100					
Fiber A	Fiber B	0%	20%	40%	60%	80%	100%
M50J	M60J	-0.21	-0.14	-0.06	0.02	0.11	0.21
YS-35	YS-60	-0.39	-0.24	-0.07	0.18	0.41	0.74
K149	YS-70	-0.55	-0.36	-0.11	0.28	0.93	2.24

(Note)

Lamination direction: 0°, 90°, +45°, -45°, -45°, +45°, 90°, 0°

Vf= 60%

As shown in Table 2, it would be found a minimum coefficient of thermal expansion depending on the hybrid ratio. Hybrid ratios of reinforced fibers of which a total coefficient of thermal expansion is zero are shown in Table 3.

Table 3: Weight ratio of Fibers A and B, and elastic modulus in the case that an in-plane coefficient of thermal expansion is zero

Fiber type		Weight of fiber (%)		Elastic modulus (kg/mm^2)
Fiber A	Fiber B	Fiber A	Fiber B	
M50J	M60J	55.1	44.9	11,328
YS-35	YS-60	44.6	55.4	10,619
K149	YS-70	45.4	53.6	10,099

(Note) Vf=60%

(4) In the case of a triaxial textile, an in-plane quasi-isotropic characteristic can be obtained by one textile sheet. In such a case, a crimp ratio is varied depending on its thickness. Therefore, it has been checked ratios of textile having thickness of 0.1mm and 0.2mm.

(a) A relation between a hybrid ratio and a coefficient of thermal expansion of composite material formed by a triaxial textile having a thickness 0.1mm calculated from the above equation

Table 4: Hybrid ratio of fiber and in-plane thermal expansion coefficient (unit:ppm/℃)

Fiber type		Hybrid ratio (%) = weight of fiber A/(weight of fiber A + weight of fiber B) x 100					
Fiber A	Fiber B	0%	20%	40%	60%	80%	100%
T300	Zairon	-2.86	-1.98	-1.04	-0.04	1.04	2.19
K149	Zairon	-2.86	-2.11	-1.26	-0.27	0.89	2.26
M35J	Zairon	-2.86	-1.98	-1.17	-0.03	0.27	0.92

(Note)   thickness of triaxial textile: 0.1mm

Vf = 60%

As similarly, the hybrid ratio is shown in Table 5 in the case that a thermal expansion coefficient of the combined fibers as shown in Fig. 4 is zero.

Table 5:   Weight ratio of fibers A and B, and elastic modulus of which an in-plane thermal expansion coefficient is zero.

Kind of fiber		Weight of fiber (%)		Elastic modulus (kg/mm^2)
Fiber A	Fiber B	Fiber A	Fiber B	
T300	Zairon	60.7	39.3	5,729
K149	Zairon	65	35	5,038
M35J	Zairon	72.1	27.9	7,221

(Note) Thickness of triaxial textile: 0.1mm

Vf=60%

(b)   Table 6 shows a relation between the hybrid ratio and thermal expansion coefficient of composite material made of triaxial textile having a thickness of 0.2mm calculated from the above equation

Table 6: Hybrid ratio of fiber and in-plane thermal expansion coefficient of triaxial textile (unit: ppm/°C)

Fiber type		Hybrid ratio (%) = weight of fiber A/(weight of fiber A + weight of fiber B) x 100					
Fiber A	Fiber B	0%	20%	40%	60%	80%	100%
T300	Zairon	-2.80	-1.94	-1.02	-0.03	1.05	2.22
K149	Zairon	-2.80	-2.08	-1.24	-0.26	0.90	2.31
M35J	Zairon	-2.80	-1.95	-1.16	-0.42	0.28	0.95

(Note)   a thickness of triaxial textile: 0.2mm,

Vf = 60%

As similarly, the hybrid ratio is shown in Table 7 in the case that a thermal expansion coefficient of the combined fibers as shown in Fig. 6 is zero

Table 7: Weight ratio of Fibers A and B, and elastic modulus in the case that an in-plane quasi-isotropic thermal

expansion coefficient is zero.

Fiber type		Weight of fiber (%)		Elastic
Fiber A	Fiber B	Fiber A	Fiber B	modulus (kg/mm^2)
T300	Zairon	60.6	39.4	5,713
K149	Zairon	64.8	35.2	5,028
M35J	Zairon	71.8	28.2	7,168

(Note)   Thickness of triaxial textile:0.2mm

Vf=60%

In the above embodiments, epoxy resin is used as a matrix. However, if any resins have proper characteristics, various thermoplastic resin can be used as the matrix. In addition, a matrix of composite material including resin and metal may be used if the matrix has proper characteristics.

Further, it is effective to control coefficient of thermal expansion of these resin. Characteristics of resin such as a coefficient of thermal expansion may be controlled by blending various fillers in the resin.

Although the above embodiments show an isotropic coefficient of linear expansion by providing fiber reinforced resin composite material having an in-plane quasi-isotropic characteristic, a combination of fiber bundles and prepreg disclosed in the above embodiments may be controlled in the case that a coefficient of linear expansion is different depending on its direction.

Industry Field Applicable to the Invention

In fiber reinforced resin composite material according to the present invention, reinforced fiber having various characteristics and different coefficient of linear expansion and matrix resin are combined in the above described embodiments. By controlling a coefficient of linear expansion of reinforced fibers, fiber reinforced resin composite material having a

controlled coefficient of linear expansion and preferable characteristics can be obtained. The material can be broadly utilized as a structure and a part used in a fine machinery or an air craft and space environment where varying temperature and thermal expansion caused by varying temperature are remarkably influenced.

Claims:

1. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion by combining sheets woven by one kind or more than reinforced fibers, each coefficient of linear expansion of said sheets controlled to be reduced by combining two kinds or more than of reinforced fibers wherein said reinforced fibers includes at least one kind of reinforced fibers having a negative coefficient of linear expansion.

2. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion as claimed in claim 1, said material characterized in that monofilament, yarn doubling or blending strand is used for said two kinds or more than of reinforced fibers.

3. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion as claimed in claims 1 or 2, wherein said coefficient of linear expansion is reduced by combining sheets woven by one kind or more than reinforced fibers of which a coefficient of linear expansion is controlled by a three dimensional structure of twisting yarn, biaxial textile or triaxial textile.

4. In-plane quasi-isotropic fiber reinforced resin composite material having a reduced coefficient of linear expansion by combining sheets with different coefficient of linear expansion woven by one kind or more than reinforced fibers, wherein each coefficient of linear expansion of said reinforced fibers is controlled to be reduced by combining two kinds or more than of reinforced fibers wherein at least one kind of said reinforced fibers has a negative coefficient of linear expansion.

5. In-plane quasi-isotropic fiber reinforced resin composite

material having a reduced coefficient of linear expansion selected from material claimed in at least one of claims 1 through 4.

6.   Yarn prepreg, one-way prepreg, biaxial textile, triaxial textile, four axial textile or a prepreg formed by these textile used for in-plane quasi-isotropic fiber reinforced resin composite material as claimed in one of claims 1 through 5, wherein a coefficient of linear expansion of said material is controlled.

ABSTRACT

In fiber reinforced resin composite material, in order to
reduce a coefficient of linear expansion to relatively small,
particularly to zero, two kind or more than reinforced fibers
are combined, wherein at least one reinforced fiber with a negative
coefficient of linear expansion is included, prepreg sheet formed
them are laminated so as to provide in-plane quasi-isotropic plate.
Thus, a total coefficient of liner expansion of fiber reinforced
resin composite material is controlled to zero.

A coefficient of linear expansion of doubling yarn and
combing wool combined by two kind or more than reinforced fibers
is controlled, a coefficient of linear expansion of prepreg sheet
formed by these fiber bundles is controlled or a coefficient of
linear expansion of fiber bundles formed by two kinds or more
than reinforced fibers is controlled by previously controlling
the coefficient of linear expansion of the fiber bundles and
considering an influence caused by a three dimensional structure
of doubling yarn and textile. As the result, the coefficient
of linear expansion of the composite material can be reduced as
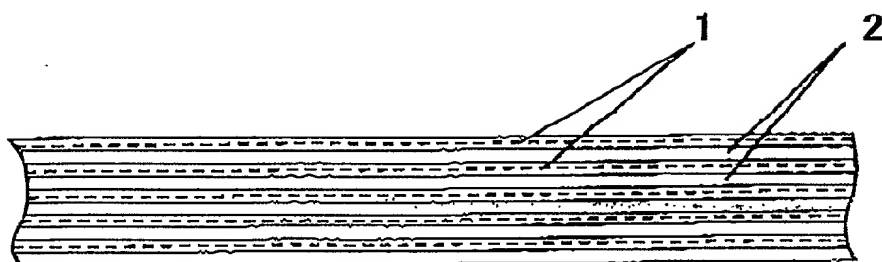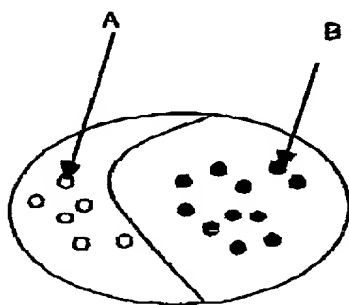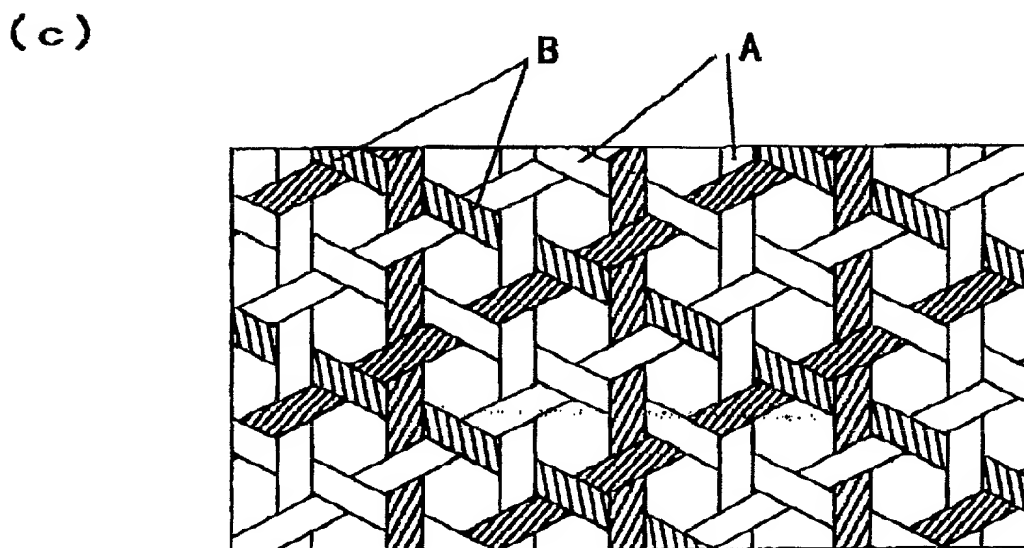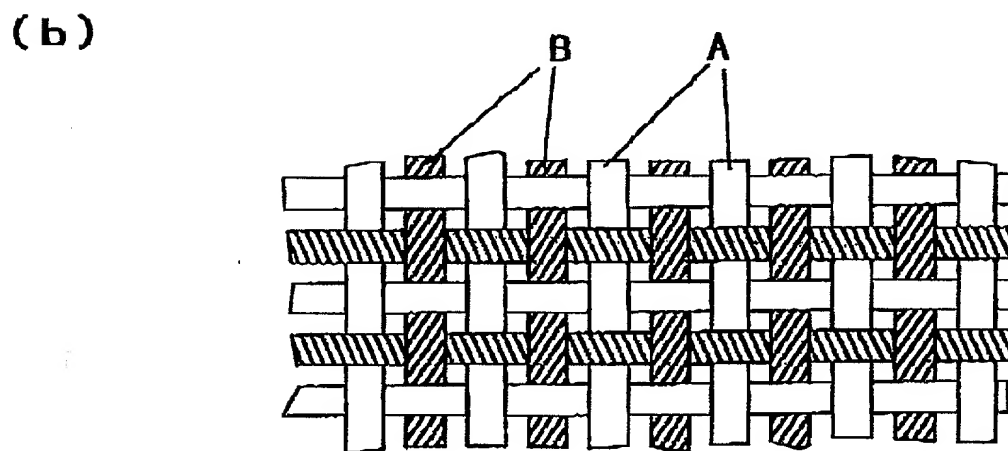less as possible.

Fig. 1

Fig. 2

09/720372
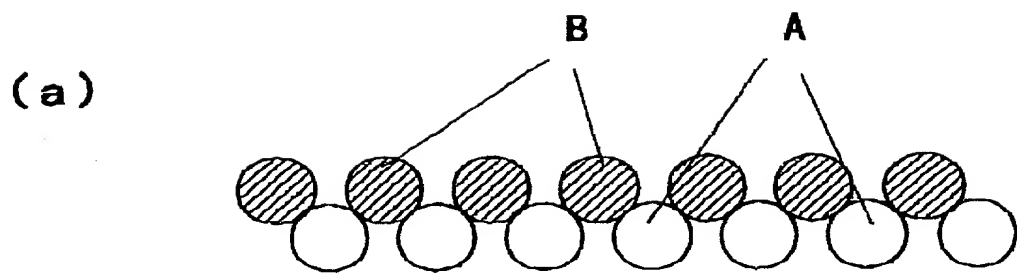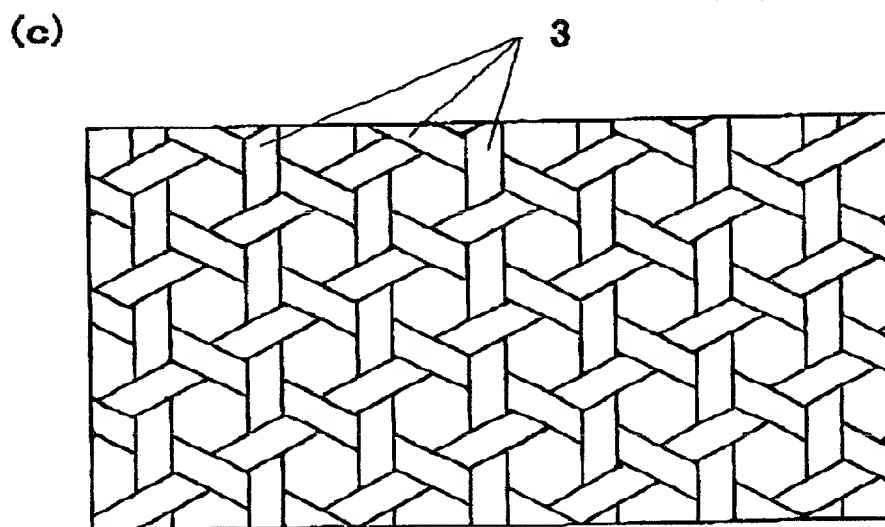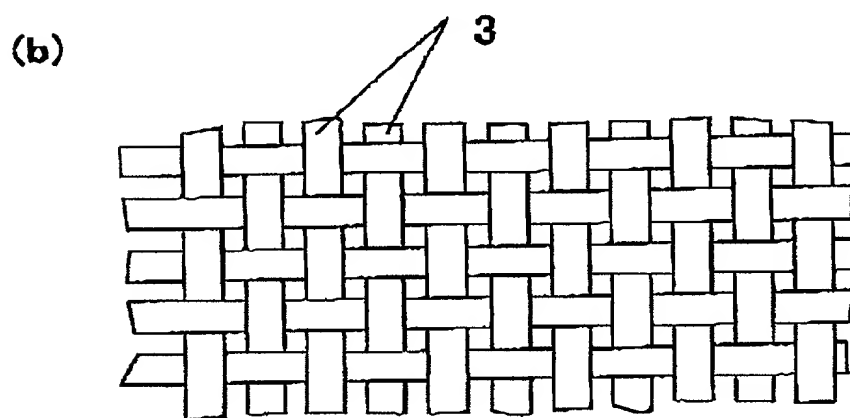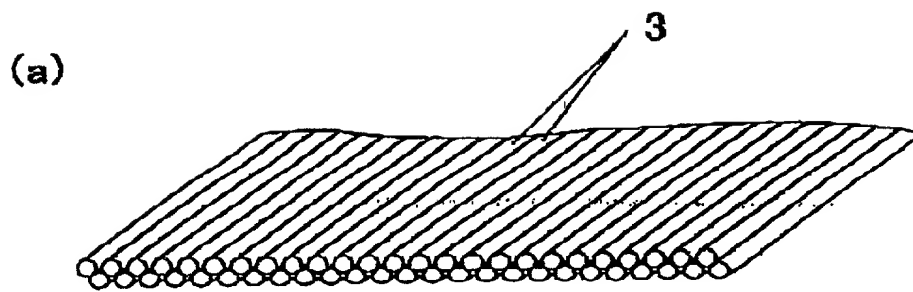
Fig. 3

(a)

(b)

(c)

Fig. 4

(a)

3

(b)

3

(c)

3

Combined Declaration for Patent Application and Power of Attorney

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; and that I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

FIBER-REINFORCED RESIN COMPOSITE MATERIAL HAVING REDUCED COEFFICIENT OF LINEAR EXPANSION

the specification of which (check one)

    [ ]   is attached hereto;

    [x]   was filed in the United States under 35 U.S.C. §111 on __December 26, 2000__, as
            U.S. Appln. No. __09/720,372__ *; or

    [X]   was/will be filed in the U.S. under 35 U.S.C. §371 by entry into the U.S. national stage of an international
            (PCT) application, __PCT/ JP00/02652__; filed __24 April__, entry requested on
            _____*; national stage application received U.S. Appln. No. _____*; §371/§102(e)
            date _____ * (* if known)

and was amended on __December 26, 2000__ if applicable).
(include dates of amendments under PCT Art. 19 and 34 if PCT)

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above; and I acknowledge the duty to disclose to the Patent and Trademark Office (PTO) all information known by me to be material to patentability as defined in 37 C.F.R. §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §§ 119 (a)-(d) and 365 (b) of any prior foreign application(s) for patent or inventor's certificate, or §365(a) of any prior PCT application(s) designating a country other than the U.S., listed below with the "Yes" box checked, and have also identified below, by checking the "No" box, any foreign application for patent or inventor's certificate or PCT international application having a filing date before that of the application on which priority is claimed:

11116270	Japan	23 April 1999	[X]	[ ]
(Number)	(Country)	(Day Month Year Filed)	YES	NO
			[ ]	[ ]
(Number)	(Country)	(Day Month Year Filed)	YES	NO

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional applications listed below:

(Application No.)	(Day Month Year Filed)
(Application No.)	(Day Month Year Filed)

I hereby claim the benefit under 35 U.S.C. §120 of any prior U.S. non-provisional application(s) or under §365(c) of any prior PCT international application(s) designating the U.S., listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in such U.S. or PCT international application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose to the PTO all information which is material to patentability as defined in 37 C.F.R. §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application No.)	(Day Month Year Filed)	(Status: patented, pending, abandoned)
(Application No.)	(Day Month Year Filed)	(Status: patented, pending, abandoned)

As a named inventor, I hereby appoint the following registered practitioners to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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The undersigned hereby authorizes the U.S. Attorneys or Agents appointed herein to accept and follow instructions from OHTA PATENT OFFICE as to any action to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. Attorneys or Agents and the undersigned. In the event of a change of the persons from whom instructions may be taken, the U.S. Attorneys or Agents appointed herein will be so notified by the undersigned.

Atty. Docket: KUBOMURA=1

Title: FIBER-REINFORCED RESIN COMPOSITE MATERIAL HAVING REDUCED COEFFICIENT ...

U.S. Application filed _____ , Serial No. _____

PCT Application filed _____ , Serial No. _____

I hereby further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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RESIDENCE		CITIZENSHIP
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FULL NAME OF SEVENTH JOINT INVENTOR	INVENTOR'S SIGNATURE	DATE
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